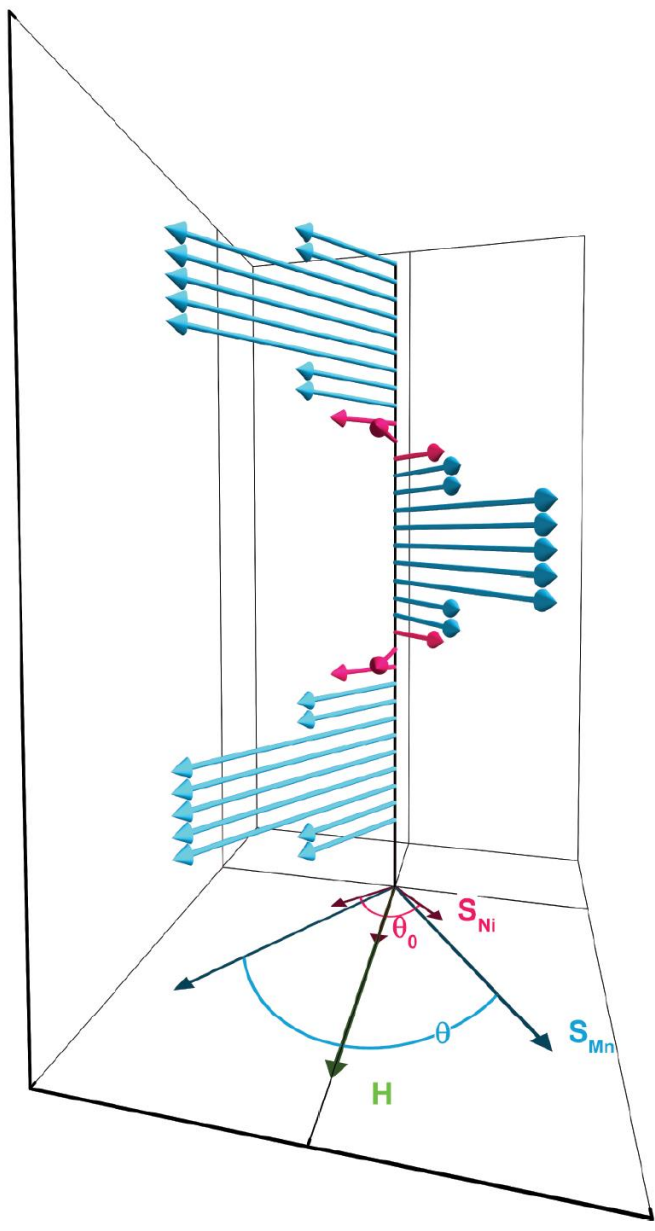


Canted magnetism in modulated thin-film superlattices

Jackson Wong, **Oliver Paull**, Daniel Sando, Wai Tung Lee, Stephen Holt and Nagarajan Valanoor

Superlattices of manganite ($\text{La}_{2/3}\text{Sr}_{1/3}\text{MnO}_3$, LSMO) and nickelate (LaNiO_3 , LNO) materials have been shown to exhibit exotic magnetism due to charge transfer at the interface that is dependent on the number of LNO unit cells in between LSMO layers. Here we extend this work by fabricating modulated superlattices with unit-cell precision that exhibit patterns of LNO thicknesses to tailor novel magnetic configurations. We use polarized neutron reflectometry on PLATYPUS with spin-flip analysis to try and determine the complex magnetic profiles of these modulated superlattices

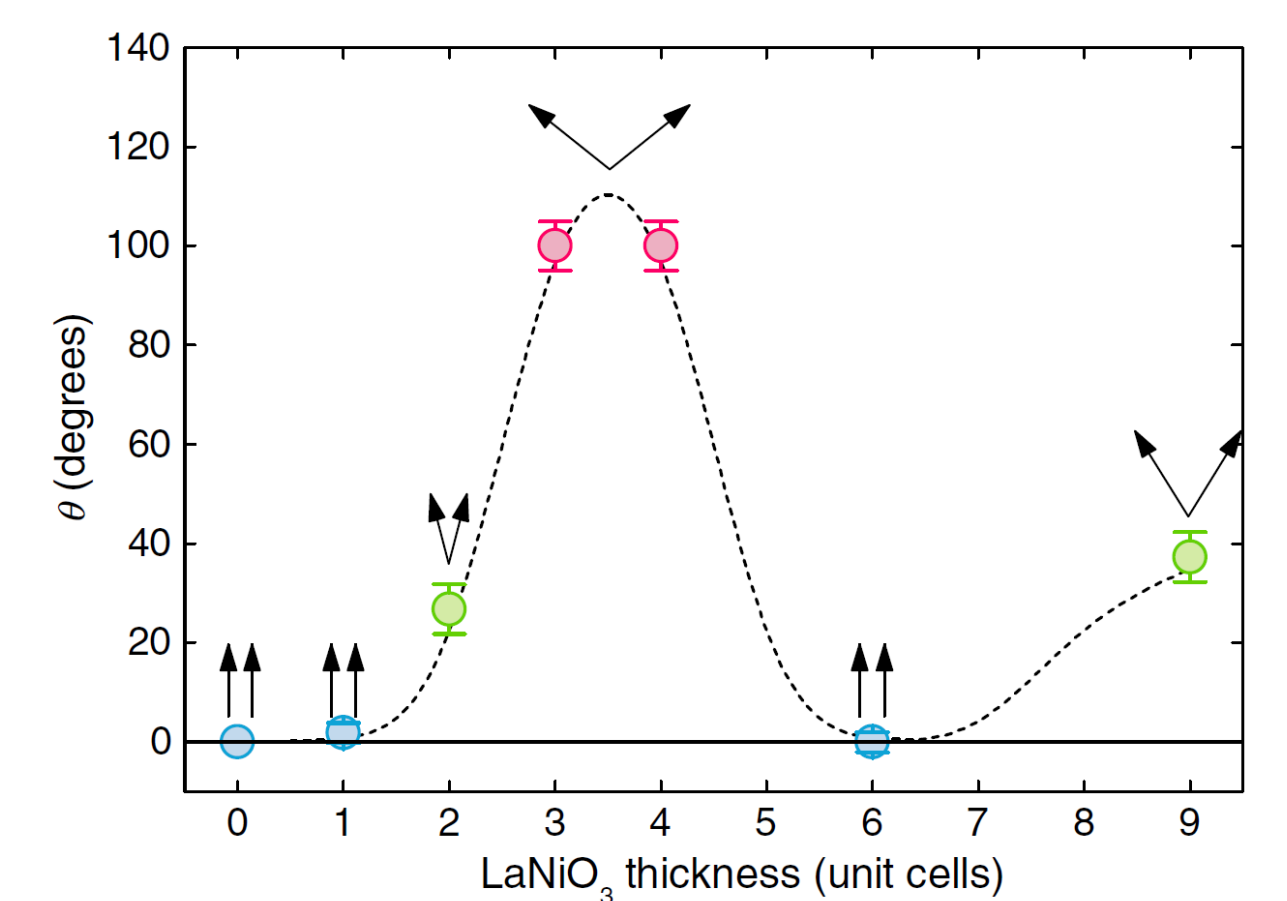
Background



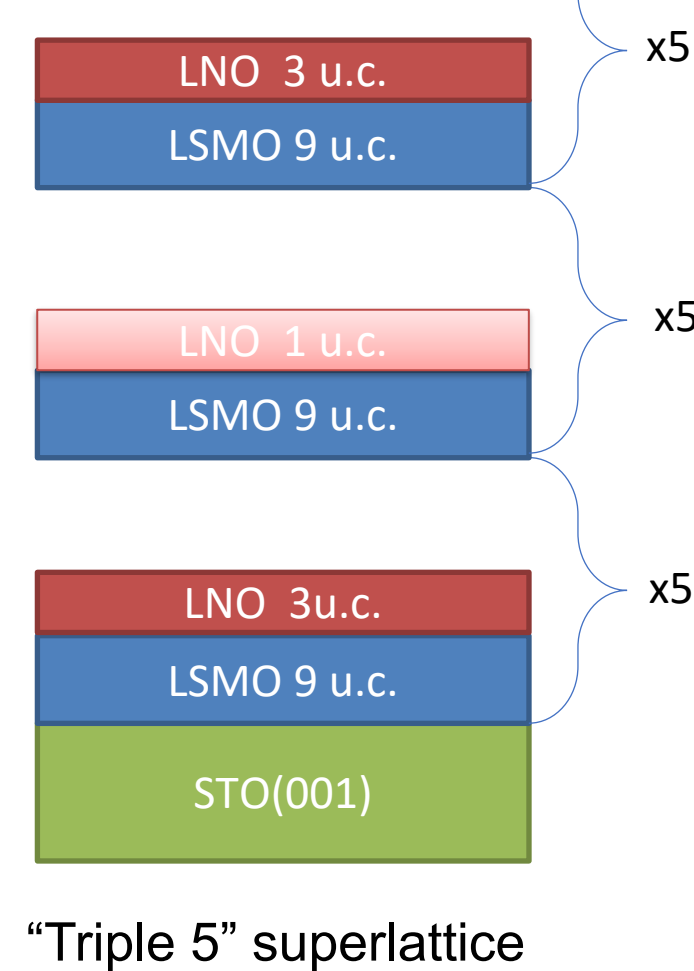
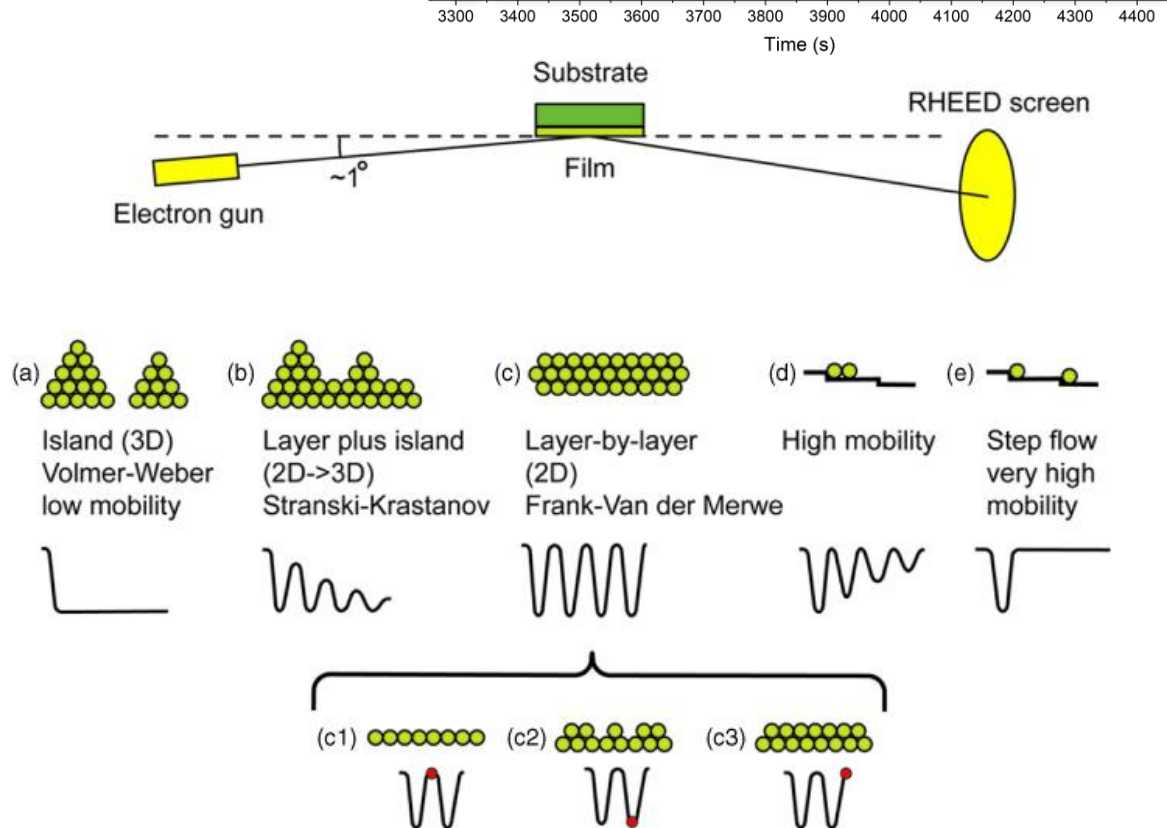
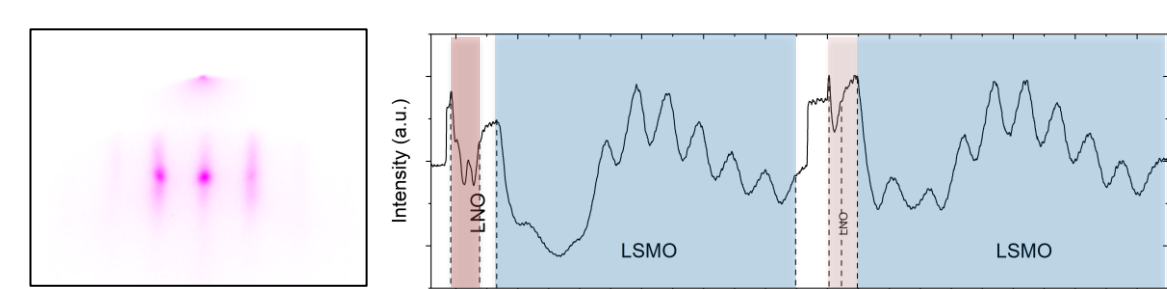
Superlattices of the double-exchange magnetic conductor $\text{La}_{2/3}\text{Sr}_{1/3}\text{MnO}_3$ (LSMO) and the paramagnetic insulator LaNiO_3 (LNO) reveal magnetic interactions resulting from charge transfer at LSMO/LNO interfaces which cause the magnetization in adjacent LSMO layers to be canted on either side of the applied magnetic field direction [1].

Critically, it was found that the LNO layer thickness determines the amount of charge transfer occurring across the LNO/LSMO interface. This charge state changes the effective exchange energy of the LNO between ferromagnetic LSMO layers, causing a canting of the magnetization in adjacent LSMO layers.

This result points to the ability to tailor the exchange energy of superlattice layers to design functionality through interlayer coupling.



Reflected High-Energy Electron Diffraction (RHEED)

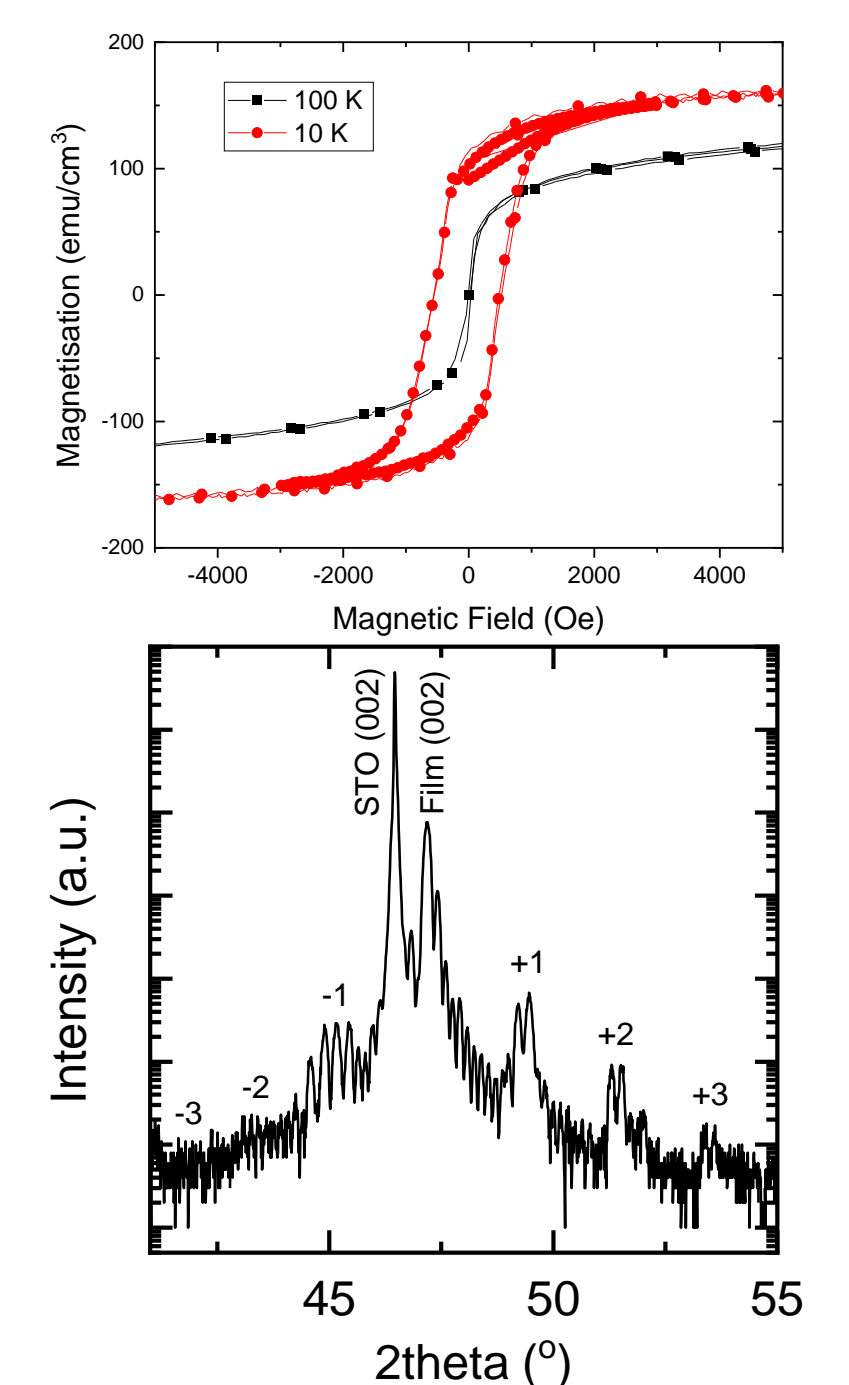


Sample fabrication and characterisation

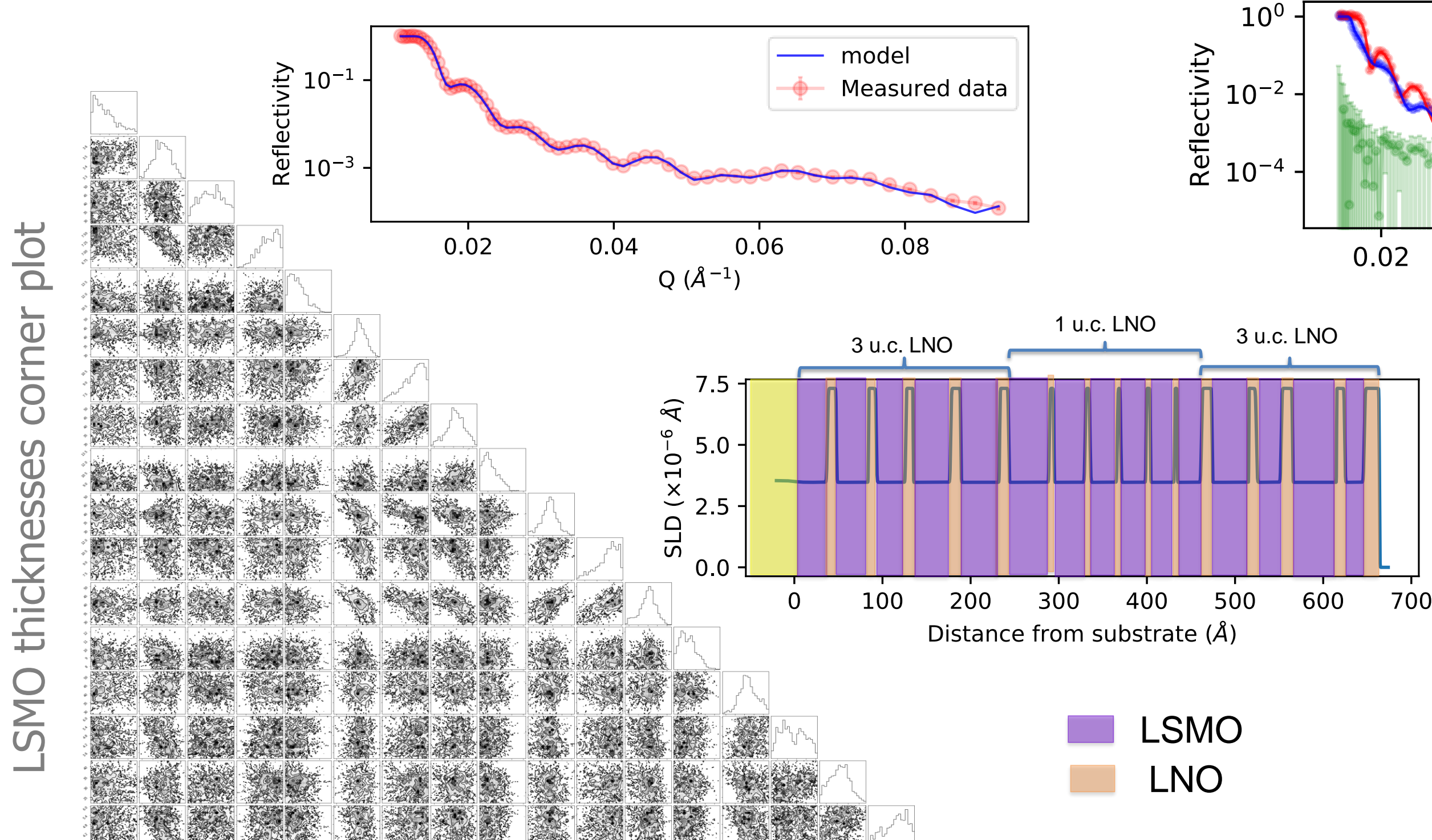
LSMO/LNO superlattices were grown using reflected high-energy electron diffraction (RHEED)-assisted pulsed laser deposition (PLD) to monitor the growth on a unit-cell level.

In all samples, each LSMO layer is held constant at 9 unit cells (u.c.), and superlattices has 15 repetitions of LSMO/LNO. The SL of interest has:

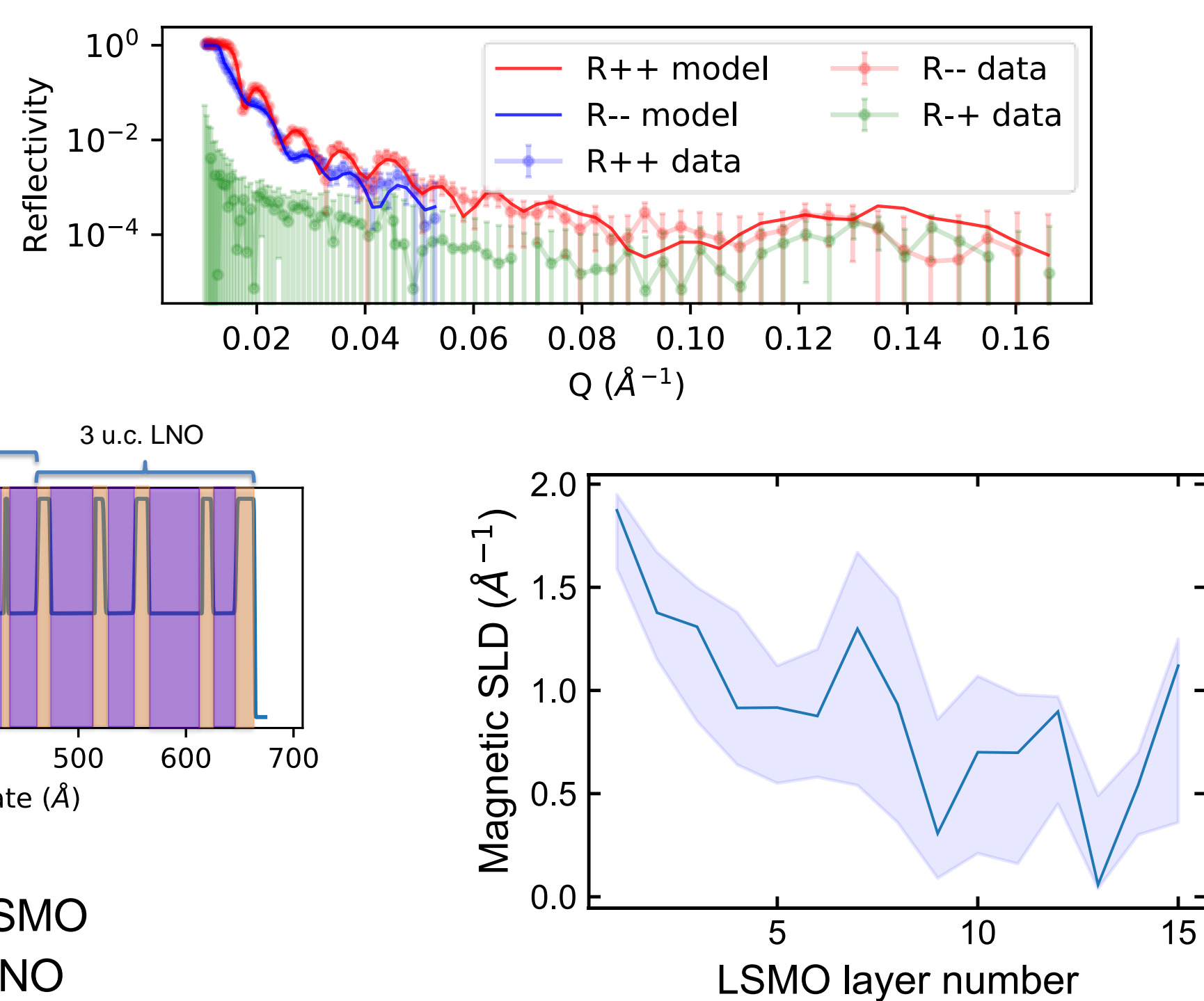
- 5 repetitions of 9 u.c. LSMO and 3 u.c. LNO (nominally producing canted magnetism)
- 5 repetitions of 9 u.c. LSMO and 1 u.c. LNO (nominally producing ferromagnetic alignment)
- 5 repetitions of 9 u.c. LSMO and 3 u.c. LNO (nominally producing canted magnetism) again.



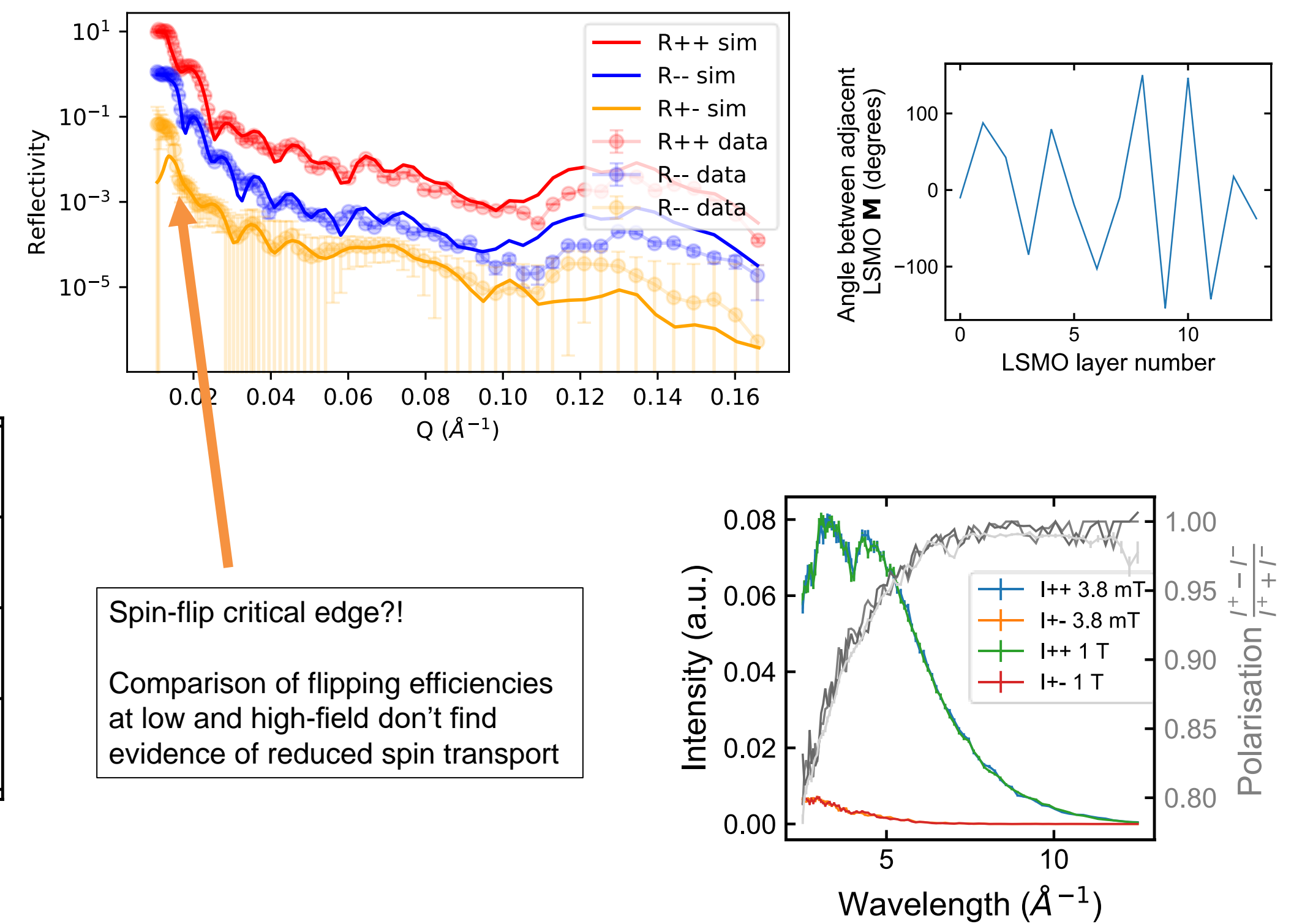
Structural refinement (unpolarised neutron reflectometry)



High-field magnetic refinement



Low-field magnetic refinement



Conclusions

- LSMO/LNO superlattices play host to magnetic interactions at the interface, resulting in complex magnetic arrangements in the overall magnetic structure.
- Using SrTiO3 substrates allows high-quality growth but is hampered by a ferroelastic transition at ~ 105 K that significantly reduces the quality of the reflected signal. This forced us to measure at temperatures where the sample has a lower net magnetization as evidenced by magnetometry
- The existence of a 'critical-edge'-like feature in the spin-flip data (SF) indicates there is an issue with the polarization efficiency of PLATYPUS, although a comparison of the flipping efficiencies between low and high magnetic fields shows no evidence of this. It could be possible to reduce the raw spectra again including an approximation of this reduced efficiency.

- Fitting the low-field datasets with spin-flip analysis shows a complex sequence of magnetic canting angles that is not as simple as that reported using a superlattice with constant LNO thicknesses throughout. Due to minor imperfections in the superlattice requiring each layer be fit individually, the number of fittable parameters becomes very large such that the uniqueness of a fitted model becomes questionable.
- Small experimental imperfections in both the sample fabrication and PNR experiment play a large part in the complexity of the model!

References

[1] – J. D. Hoffman *et al.*, Oscillatory Noncollinear Magnetism Induced by Interfacial Charge Transfer in Superlattices Composed of Metallic Oxides, *Phys. Rev. X* **6**, 041038 (2016)